# Annual Progress Report

for

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for

University of Minnesota

Data Analysis of the WAVES Experiment

for the period
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to 31 December 1995

Professor Paul J. Kellogg
Keith Goetz
University of Minnesota
School of Physics and Astronomy
Plasma Waves Lab
116 Church Street S.E.
Minneapolis, MN 55455

## Summary

This grant was awarded to the team lead by Professor Paul J. Kellogg to provide support for the University of Minnesota data reduction and analysis effort for data produced by the WAVES instrument. The WAVES instrument was launched on the WIND spacecraft on November 1, 1994. Beginning after its initial commissioning and check-out phase was completed, this grant has provided funding for all University of Minnesota WAVES data analysis.

The University of Minnesota, in cooperation with colleagues at the NASA Goddard Space Flight Center and the Paris Observatory, have collected and analyzed all available WAVES data. Numerous presentations and publications have been made. Efforts have begun at correlating results from WAVES with other experiments on WIND as well as experiments on other spacecraft.

As we continue to build on the existing WAVES data-set, the University looks forward to a long lifetime in orbit for the WAVES experiment and continued opportunities for scientific research.

## WAVES Data Acquisition

The University has acquired all WAVES level-0 telemetry data during the first year of the WIND mission. In addition to the WAVES data, Key Parameter data from the other WIND investigations has been collected when available. Spacecraft orbit and attitude data have also been collected. Typically, one file of each of these classes of data is generated per day. These files have been collected and stored on-line on the Lab's computer system such that all WIND telemetry is available on-line at all times.

With each new day of data, the Minnesota team has processed the data to ensure the continuing health and safety of the WAVES instrument. Several anomalies were found during the first year which required some recovery on the part of the WAVES team. It is essential that this health and safety monitoring be done in a timely manner which has been done during the first year.

The WAVES level-0 data received each day has also been examined scientifically. Each day the Lab produces a number of standard data products (graphs) for that day's data in order to quickly summarize the scientific data during the day and indicate interesting periods for further analysis.

## Instrument Commanding

In addition to the reception and analysis of WAVES data the WAVES instrument requires a detailed commanding schedule which must be defined and submitted to the WIND Flight Operations team well in advance of the observations. The merging of science requirements into the observation schedule must be done to allow the maximum scientific return. These command schedules, microprocessor uploads and observation coordination have been performed at Minnesota during the first year of the WIND mission and will continue to be done at Minnesota during the second year of the mission.

## Ground Software

Before the launch of the WIND spacecraft, the University of Minnesota, along with collaboration from the broader WAVES team developed a library of data access tools for use with the WAVES instrument. During the first year of the WIND mission, that software has been updated and ported to a number of platforms where it is in daily use by many WAVES team members.

WINDlib now allows users to access various WIND Key Parameter values as well as the spacecraft orbit and attitude information. It also allows simple access to the Key Parameters, Orbit and Attitude information from other GGS missions (i.e. GEOTAIL and POLAR). The WINDlib software package also allows scientific users to access fully calibrated measurements in *physical units.* This means that WAVES users can all use the same calibration technique which enhances scientific productivity. These capabilities were added to WINDlib during the first year of the WIND mission. WINDlib is also used by the GGS CDHF computer system in the generation of the WAVES Key Parameters. As such the software library has been ported and installed on the CDHF computer.

As the University of Minnesota worked to understand the data obtained during a passage of the WIND spacecraft through the shadow of the moon, it became clear that there was some ambiguity in the exact location of the moon. It was eventually shown by Minnesota that the NASA Satellite Situation Center was using, and supplying to the Space Physics community, a slightly incorrect value for the location of the moon. This problem has since been corrected by the Satellite Situation Center.

In addition to the continued evolution of WINDlib, a tool for data analysis, the Lab has also worked to develop a number of computer programs and techniques for the analysis and display of WAVES data from a scientific point of view. This has involved developing a number of routines to produce line graphs and spectrograms of WAVES data. We have also developed routines to combine the signals from several orthogonal search coil measurements in order to determine the direction of wave propagation. The WAVES Time Domain Sampler produces time series snapshots of electric or magnetic field events. The digitization of analog signals into digital telemetry values on the spacecraft has a few recurring systematic errors. After working with the data for the first year, we have developed some techniques to identify and sometimes correct those errors which allows us to work with higher quality TDS data.

## Published Papers

"WAVES: The Radio and Plasma Wave Investigation on the WIND Spacecraft," *Space Science Review*, **71** (1995).

"Observations of Plasma Waves During the Traversal of the Moon's Wake," accepted for publication in *Geophys. Res. Lett.* (1995).

"Early Wind Observations of Bow Shock and Foreshock Waves," submitted to *Geophys. Res. Lett.* (1996).

## Presentations

"Wire Antennas for Low-Frequency Electric Field Measurements in Tenuous Plasmas," Chapman Conference in Los Alamos, 1995.

"Waves on the Moon's Wake," Spring Meeting of the AGU, 1995.

"Observation of Whistler Waves in the Vicinity of the Earth's Bow Shock," Spring Meeting of the AGU, 1995.

"Neural Network Tracking and Quantification of the Thermal Plasma Line Observed by the Thermal Noise Receiver (TNR) Portion of the WIND/WAVES Experiment," Spring Meeting of the AGU. 1995.

"Observations of Solar Type III Radio Bursts and Associated Electrostatic and Low Frequency Waves," Fall Meeting of the AGU, 1995.

"Time-Resolved Observations of Langmuir Waves in the Solar Wind with WIND," Fall Meeting of the AGU, 1995.

## Areas of Scientific Interest

With the growing data-set and increased understanding of instrument response and function, we are beginning to correlate observations with the spacecraft position in the magnetosphere to form new scientific ideas. In addition to the publications and presentations list above, work has been done and continues in the following areas:

In examining Time Domain Sampler data at times when WIND is in the magnetopause, we have discovered that there are always very **narrow spikes** in the electric field. These spikes are not very large - of the order of 1 mV/m. Their widths, of the order of 50 microseconds, are so short that they must be temporal, (i.e. there is not time for them to be convected past the antenna). Work on these is just beginning, but we find them completely puzzling. We are confident that they have not been seen before, since no instrument with sufficient time resolution has every flown in this region.

We have identified a structure we will call **magnetic solitons**. These are short, usually circularly polarized, magnetic noise bursts in the 10-100 Hz range. They are also found mainly in the magnetosheath and magnetopause. The Japanese have found something which we think is similar in their GEOTAIL data, and have (private communication with Matsumoto) found that they are correlated with Kp. This suggests that they have something to do with magnetic reconnection.

Work continues concerning **foreshock waves**. There is a suspicion that what we interpreted as 3-wave parametric decay in our "Early Observations" paper, are actually Langmuir waves trapped in density cavities, and we intend to check this out.

At the December 1995 Wind-GEOTAIL meeting at Berkeley, we suggested that it would be good to try to see **magnetic holes** on two spacecraft, since we have no idea of their physical size, nor how long they last. After looking at a number of times when the orbit of WIND may have been close to the orbit of GEOTAIL, we have found no candidate periods for further research. While this project is stymied for now, we will continue to look for periods of interest in the future.

In addition to the above, we also plan to continue work on a number of other subjects: Langmuir waves in regions other than the foreshock; Bow shock physics; Micro structure of bow shock; Wave-particle interactions (with 3dP).

## Graduate Student

A graduate student, Scott Doudrick, is working on the magnetic soliton problem. He has developed software to determine the direction of propagation as well as the polarization of these waves.

## Funding Shortfall

During the first year of the WIND mission, Minnesota received somewhat less funding than was proposed. As a result, a number of development issues have been somewhat delayed. Most seriously impacted by the budget shortfall has been the continuing development of WAVES flight software. While the WAVES instrument continues to function quite well, a number of scientific enhancements were planned for development **after** launch but have not yet been fully implemented. Limited funding has, at least in part, been responsible for slow progress in this important area.

We originally proposed to purchase an RDAF (Remote Data Access/Analysis Facility) for the purpose of WAVES data analysis and archival. Because funding at Minnesota was tight, we delayed this purchase until the end of fiscal year 1995. At that time, enough of the first year's funding remained such that, along with a corporate grant awarded the Lab by the Digital Equipment Corporation, we were able to procure the core components of a central RDAF which should provide enough processing capability for the duration of the prime WIND mission. Without Digital's corporate sponsorship, our funding level from this grant would have been inadequate to allow us to add this key component in the Minnesota data analysis system.

Because of our reduced funding situation for WIND data analysis at Minnesota, we have begun discussions with Minnesota Physics Professor Cindy Cattell here to have some of her own research students look at some WAVES magnetospheric data, which we have don't have the resources to do.